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# A primary study on a long-term vision and strategy for the realisation and the development of the Sahara Solar Breeder project in Algeria

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ABSTRACT

Energy security, economic growth and environmental protection are the national energy policy drivers of any country of the world. Scientists, governments, and industries are witnessing the long-term consequences of energy consumption and foresee catastrophic outcomes if alternative methods of energy production are not developed and utilised to meet the needs of our global economy. In recent years, PV is proposed as a competitive energy policy and a step forward to the target of sustainable development and environmental friendly energy source. In this contribution a particular attention is being given to the joint event that bring together the relevant parties, the University of Sciences and Technology of Oran (USTO), Japan International Corporation and Japan Science and Technology Agencies (JICA, JST) to develop a long-term vision and strategy to boost the ideas for the realization and the development of the Sahara Solar Breeder (SSB) project. SSB advocates the view of undertaking collaborative basic, applied and development research, as well as industrial production and technical, commercial and financial support services to implement photovoltaic solar energy systems. The strategic objective is the establishment of a Global Clean Energy Superhighway as the solution to global energy challenges, water shortages, levelling of electric power supply in the world, climate change and other environmental problems arising from the current fossil-fuel heavy global energy paradigm [1]. This project will tackle the key challenges and issues related to the field of PV putting forward the USTO perspective and promoting its R/D activities by a collaborative research plan between Japan and Algeria. This event also seeks to identify the most important challenges facing both the research and economic sectors and put forward new strategies that will identify the required skills to transform the research prospects of USTO based on the analysis and prospect of elementary processes and system design.



**Contents**



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## 1. Introduction

Energy is considered a prime agent in the generation of wealth, and a significant factor in economic development of the world's nations. The global demand for energy is rapidly increasing with increasing human population, urbanization and modernization and is projected to rise sharply over the coming years. Energy consumption in developed countries grows at a rate of approximately 1% per year, and at a rate of 5% per year in developing countries [2]. The future demand for electricity, assessed from time to time by the International Energy Agency (IEA), shows that the world's electricity consumption is expected almost to double by the year 2020 [3].

At present, the bulk of our energy comes from fossil fuels (gas, coal, and oil). These are hydrocarbons composed of hydrogen and carbon atoms which when combined with the oxygen in the air and heat, they react exothermically. Atmospheric and environmental pollution as a result of extensive fossil fuel exploitation in almost all human activities has led to some undesirable phenomena that have not been experienced before in known human history. Fossil fuel consumption continues to increase and emissions have increased dramatically over the past century in that, massive amount of carbon dioxide in the atmosphere has dire implications for the delicate balance of our ecosystem and could eventually lead to runaway climate change. Such phenomena are varied and include global warming and the greenhouse affect (Fig. 1 [4] and Table 1 [5]), ozone layer depletion, acid rain, hazardous air quality and water pollution, forest destruction and major environmental accidents.

World oil production will decline in the next 20–40 years and dependence on energy from fossil fuels is also reaching its limits (Fig. 2) [6], the development of new power generation technologies will become increasingly important. Simultaneously, interest will likely increase regarding energy-related environmental concerns to take precautions today for a viable world for coming generations. Hydrocarbons energy sources cannot be expected to fill that increased demand and should not be, for both environmental and practical economic reasons (Fig. 3) [7]. Indeed, energy is one of the main factors that must be considered in discussions of sustainable development. The global energy economy will need to decarbonise power generation substantially in order to achieve a sustainable energy future. This will require large-scale shifts to renewable energy for power generation. Solar radiation is an integral part of different renewable energy (RE) resources, in general, and, in particular, it is the main and continuous input variable from the practically inexhaustible sun. Solar energy is expected to play a very significant role in the future especially in developing countries, but it also has potential in developed countries.

The International Energy Agency has identified photovoltaics (PV) as one of the key technologies that are at the heart of the energy technology revolution because they can make the largest contributions to reducing greenhouse gas emissions.


**Fig. 1.** Total global fossil carbon emissions.

**Table 1**
Global $CO_2$ emissions in tons/capita (2008).

| USA | Australia | Russia | Japan | E.U. | World average |
|---|---|---|---|---|---|
| 19 | 19 | 11.1 | 9.5 | 8.1 | 4.3 |
| M. East | China | E. East | L. America | Africa | |
| 6.8 | 6.8 | 2.8 | 2.1 | 0.9 | |

This paper introduced the major global energy challenges and analyzed the development and utilisation of alternative methods of energy production to meet the needs of our global economy. A particular attention is being given to the development and realisation of the Sahara Solar Breeder (SSB) project in the Sahara of Algeria which covers a total area of 2,048,297 km$^2$, approximately 86% of the total area of the country. This project will tackle the key challenges and issues related to the field PV putting forward the material R/D perspective and promoting innovative processes for solar silicon with a focus on the utilisation of Sahara sands. Three Ss should be the national energy policy drivers of Algeria namely: Solar, Sand and Space. A primary project analysis framework is then synthesized and analyzed by clarifying the basic concepts and summarizing the main strategic ideas of SSB plan is directed towards continental and global clean energy supply from the Sahara making PV a significant contributor within a portfolio of energy sources in the coming 10–20 years.

## 2. Renewable energies potentials in Algeria

Due to its geographical location, Algeria holds one of the highest solar reservoirs in the world. Studies of RE sources performed in Algeria during recent years show that it has an important potential for power generation from RE, for the domestic market as well as for export to the European market. Pilot implemented projects justify the possibility to accelerate the use of indigenous energy resources, particularly for electricity supply. The assessment of potential is based on two different types of sources: assessment of the Algerian government and the in-depth studies conducted by the German Aerospace center (DLR). DLR calculated data mainly from satellite imaging and further processing to derive technical and eventually economic potential. Table 2 summarises the RE potentials for electricity generation (power production in Algeria in 2005 stood at 35 TWh [8]). The major advantage of DLR study is that all RE potentials were assessed with an identical set of methodologies.

There is a large difference between potential of thermal and PV solar economic potential. This is somewhat distorting because at the time when the assessments of potentials were made, the cost difference and expected cost differences in the near future were very large. However, this situation has changed significantly during the last three years as PV technology prices decreased sharply; hence, investment costs for power plant investors have decreased. The effect is an increase in the economically utilisable potential on the PV side, which will lead to a decrease of thermal solar potential.

In addition to DLR study, the Center for Development of Renewable Energies (CDER) surveyed several type of RE. Data are gathered in the RE guide report by the ministry of energy and mines (MEM). This latter concludes that the biggest potential of RE in Algeria is solar as seen in Table 3 and Fig. 4 [9].

## 3. Photovoltaics, the alternatives of fossil fuels

Admittedly, the future might not see the same degree of dependence on oil and gas as alternative and renewable energy sources should be employed to close the supply-demand gap. Solar energy is becoming more practical and widely applicable as solar PV is

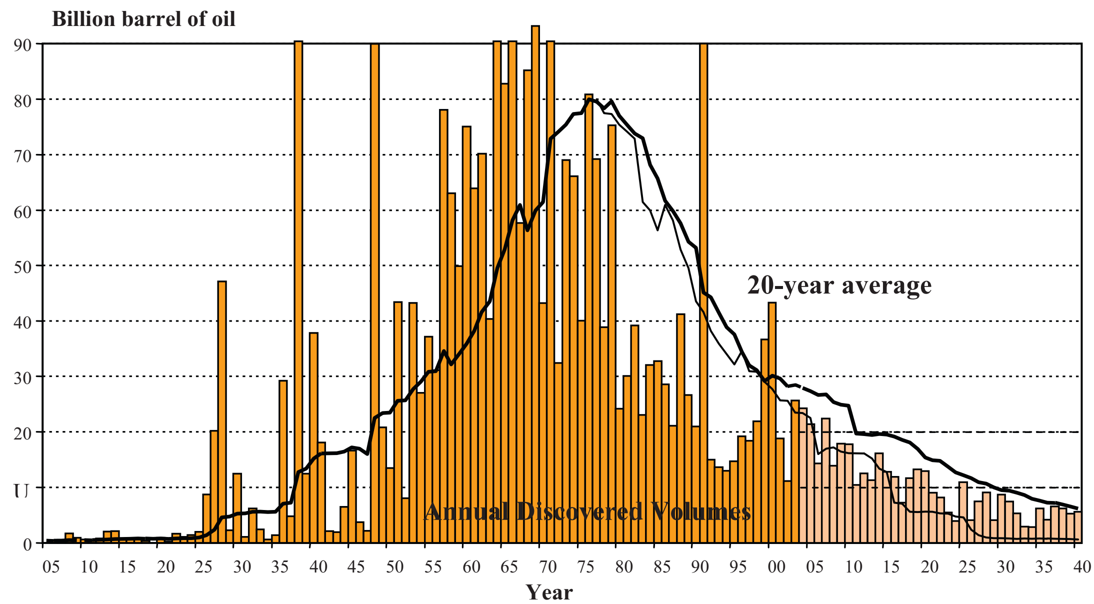


**Fig. 2.** Confronting the supply challenges, annual discovered volume of oil (1905–2040).

**Table 2**
Economic electricity supply side potential of RE in Algeria (TWh/year).

| RE in Algeria | Thermal-solar | PV-solar | Wind-power | Hydro-power | Geothermal | Biomass |
|---|---|---|---|---|---|---|
| Economic potential | 168,972 | >13.9 | 35 | 0.5 | 4.7 | 12.1 |

positioned to meet the energy-sector demands worldwide in the coming 20 years. PV systems are among the most promising electrical generation technologies to emerge in recent decades in that:

- Available anywhere and used for the everyday electricity needs.
- Constantly replenished and will never run out.
- Clean and noiseless and has distinct advantages that avoid:

  - consuming resources and degrading the environment through polluting emissions,
  - oil spills, and
  - toxic by-products.

And therefore provides:

- Flexible and environmentally acceptable energy conversion technology for a whole range of applications,
- potential in the stationary and portable power,
- limit to the damage of world environmental health and global warming.

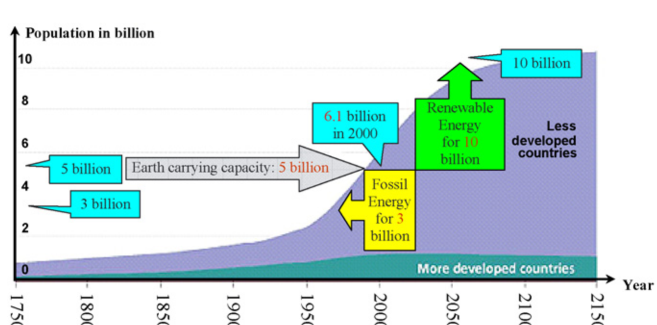


**Fig. 3.** World population growth and carrying capacity of Earth.

### 3.1. *Photovoltaic's value*

Photovoltaics have a variety of attributes that are:

- Reliable power and power quality.
- Plentiful power where you need it.
- High value and appropriate applications.
- Environmental quality in that:
  - typically, on an annual "per kilowatt" basis, PV offsets up to 16 kg of $NO_x$, 9 kg of $SO_x$, and 6 kg of other particulates, and
  - 1 kW of PV typically, per year, offsets between 600 and 2300 kg of $CO_2$ (depending on the fuel mix and solar insolation) and prevents each month, 75 kg of fossil fuel from being mined, and 473 L of water from being consumed [10].
- PV value is straightforward and truly the power of choice that provide a more stable energy environment and economy.
- The IEA projects that 3000 GW of new capacity will be required by 2020, valued at around 3 trillion of Euros; IEA also projects that the fastest-growing sources of energy will be supplied by renewables in particular solar PV.

## 4. Photovoltaics in Algeria

The high level of insulation in Algeria, the presence of several Solar projects financed and promoted by national and private industry as well as the experience in solar energy techniques by New Energy of Algeria (NEAL) are all factors that will undoubtedly

**Table 3**
Solar potential in Algeria.

| Areas | Coastal area | High plateau | Sahara |
|---|---|---|---|
| Surface (%) | 4 | 10 | 86 |
| Average duration of sunshine (h/year) | 2650 | 3000 | 3500 |
| Received average energy (kWh/m$^2$/year) | 1700 | 1900 | 2650 |

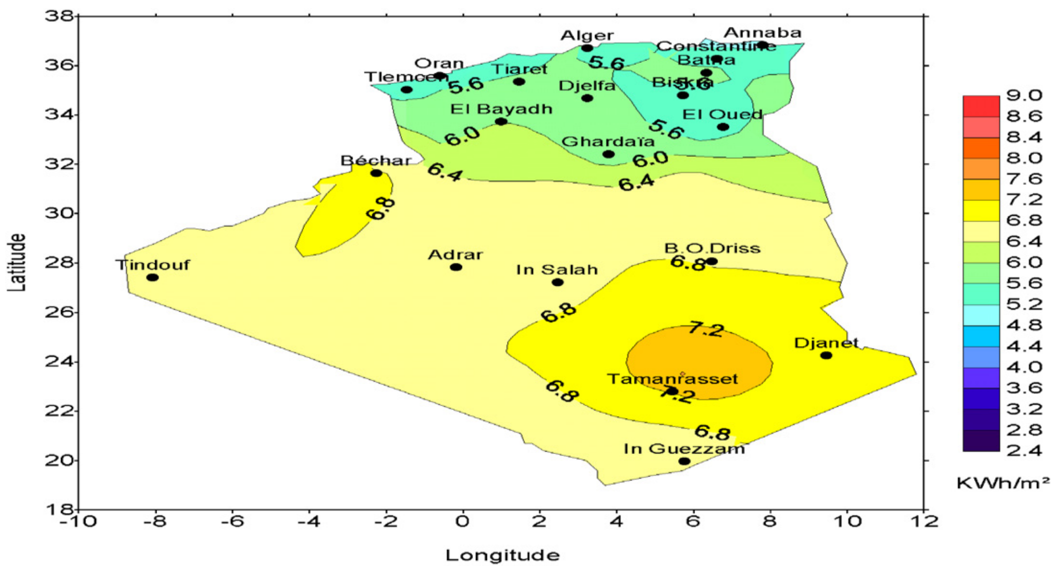


**Fig. 4.** Potential sites for solar electricity supply and example of the overall daily exposure received (in kWh/m$^2$/day) in Algeria.

give Algeria an important role in the implementation of PV energy technology in MENA region, the capacity for providing sufficient energy for the needs of the population, and the possibility of even exporting such projects to other countries in Europe.

The population distribution in Algeria also shows that there is a great potential market for renewable energies, among which solar energy should be highlighted because of its homogeneous presence throughout the entire region [11].

The amount of solar radiation in Algeria means that it would be feasible to consider solar energy as a potential energy source for different applications in the form of individual PV solar panels or systems (Fig. 5). Solar PV energy is being developed in Algeria mainly for 6 applications: domestic uses, water pumping, refrigeration, village electrification, lighting, and telecommunication.

## 5. Sahara Solar Breeder, a new global climate policy

Scientists, governments, and industries are witnessing the long-term consequences of energy consumption and foresee catastrophic outcomes if alternative methods of energy production are not developed and utilised. Photovoltaic is the alternative methods of energy production to meet the needs of our global economy. PV plants can be built over a wide size range from 2 kW to more than 500 MW and are thus adaptable to local requirement. They can also be used for combined heat/cold and power generation (co-and tri-generation) and for desalination. The largest PV plant is in the range of 60 MW.

The SSB plan involves building manufacturing plants around the Sahara desert that would extract silica from the sand and turn it into solar panels to generate renewable energy. The renewable energy from the first facility will then be used to breed more manufacturing plants and, in turn, more solar panels to generate ever increasing amounts of solar power. The ultimate goal is to build enough plants until the breeding strategy can deliver 100 GW of electricity to provide 50% of the world's electrical power generation capacity by 2050 which would be delivered via a global superconducting electrical grid to turn the world's biggest desert into the world's biggest power station taking advantage of two resources that are found in abundance in the Sahara namely silica and sunlight (Fig. 6) [12]. Embracing North Africa region's considerable potential as the world's renewable energy powerhouse.

In August the 4th 2010, USTO and JICA formed a joint group and signed a series of Memorandum of understanding and bilateral agreements to announce the creation of a Sahara Solar Energy Research Center (SSERC), at the University of Science and Technology of Oran (USTO), to pursue the realisation and the development

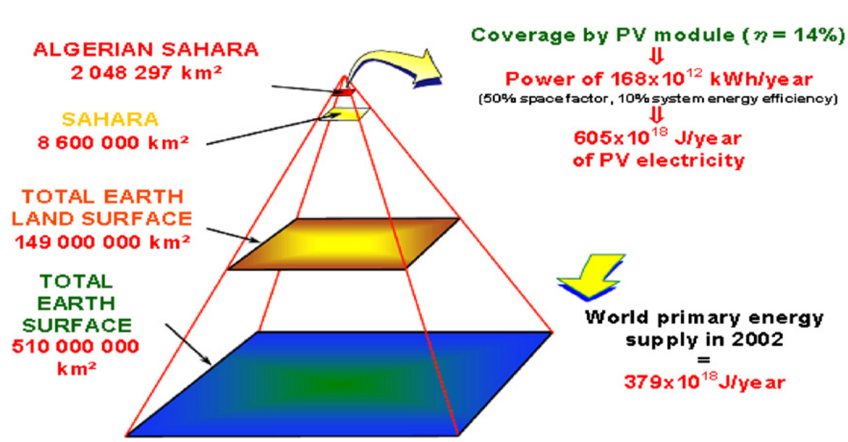


**Fig. 5.** Solar pyramid, the Algerian desert, dead space can be a treasure island of energy used by humanity.

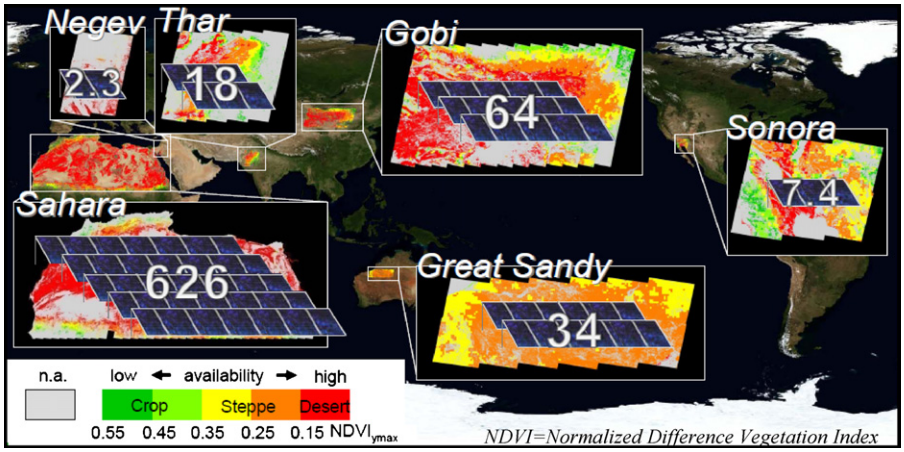


**Fig. 6.** Solar resources of the world 6 deserts (TW).

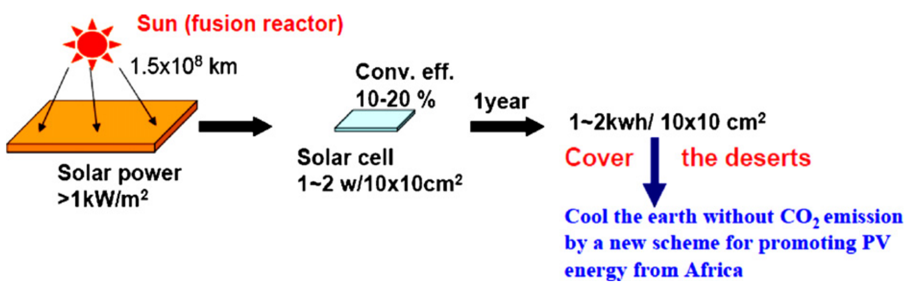


**Fig. 7.** Photovoltaic system using the photoelectric effect of turning light energy into electricity.

of PV plant at the chosen experimental site at the University of Saida in the south west of Algeria also known as the gate of the Algerian Sahara.

The development and realisation of the SSB project, in the Sahara of Algeria which covers a total area of 2,048,297 km$^2$, approximately 86% of the total area of the country, will tackle the key challenges and issues related to the field of PV putting forward the material R/D perspective and promoting innovative processes for solar silicon with a focus on the utilisation of Sahara sands. Three Ss should be the national energy policy drivers of Algeria namely: Solar, Sand and Space.

SSB, is a project which proposes a plan of international partnership in basic research and development, industrial production, trade, financing, etc., to construct, gradually over the coming decades, a "Global Clean Energy Superhighway" starting in the Sahara desert in North Africa (beginning from Algeria).

SSB will help migrate from the unsustainable current excessively fossil-fuel-based global energy paradigm to a more sustainable one. It will also help meet global energy challenges, and mitigate climate change and other environmental problems. SSB is more than an energy solution. It is an integrated community, socio-economic, industrial, agricultural, environmental, and science and technology development solution. In particular, through desalination and adequate irrigation technologies, it will help mainstream marginal desert water resources and lands back into national, regional and international development processes. The concept of

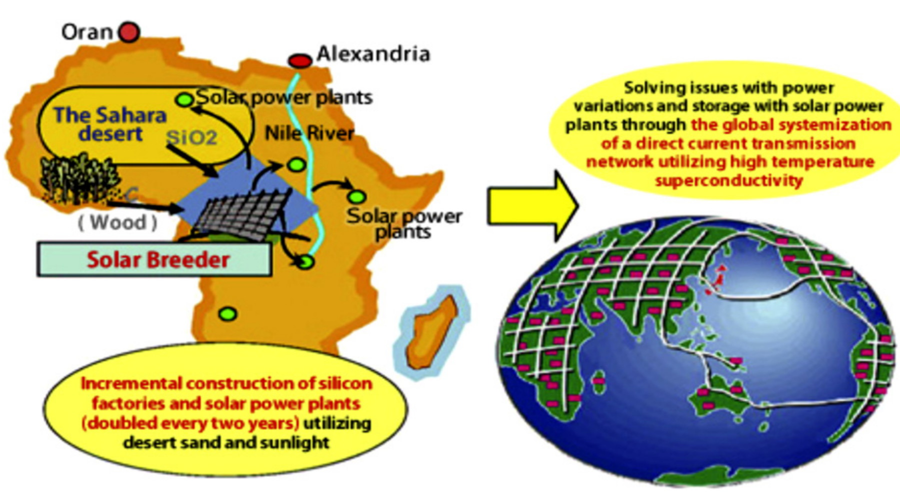


**Fig. 8.** SSB concept and plan.

**Table 4**
Solar cell materials and power generation capability.

| Material | Type | Thickness (μm) | Conversion efficiency (%) | Element | Wp/g | Ressouce ($10^3$ tonnes) | Capability of power generation (GW) |
|---|---|---|---|---|---|---|---|
| c-Si | W | 200 | 20 | Si | 0.1 | ∞ | ∞ |
| | TF | 20 | 15 | Si | 0.75 | ∞ | ∞ |
| A-Si | TF | 0.7 | 10 | Si (H) | 19 | ∞ | ∞ |
| InP | W | 200 | 25 | In | 0.33 | 1.68 | 0.56 |
| | TF | 2 | 20 | In | 26 | 1.68 | 44.5 |
| GaAs | W | 200 | 25 | Ga (As) | 0.49 | 110 | 53.9 |
| | TF | 2 | 20 | Ga (As) | 39 | 110 | 4310 |
| $CuInSe_2$ | TF | 2 | 15 | In (Cu) | 38 | 1.63 | 64 |
| | | | | Se | 28 | 83 | 2290 |
| CdTe | TF | 2 | 15 | Cd | 27 | 555 | 15,100 |
| | | | | Te | 24 | 22 | 526 |
| Ge | W | 200 | 15 | Ge | 0.14 | 44 | 0.62 |
| | TF | 0.5 | 15 | Ge | 60 | 44 | 250 |

W: wafer and TF: thin film

the SSB is depicted in Figs. 7 and 8 [13]. Scenarios can create a vision for the future and guide decision makers.

### 5.1. SSB plan and the SSERC activities

The goals of SSB towards sustainable development are founded on four pillars namely:

- Starting from basic research and development,
- coupling PV with High critical Temperature Superconducting Cables ($HT_cSC$) for clean energy generation and energy saving transmission,
- education and training for science and technology of African people, and
- solving global crisis by international cooperation and policy.

The 3 basic strategies of the SSERC programmes and indicative targets are based on the following items:

- Innovation processes for solar silicon with a focus on using Sahara sands, the following objectives have been selected:
  - Purification of silica sand by a thermodynamics based process designed in Tokyo and Nihon universities.
  - Reduction of silica sand by carbothermal (Hirosaki University) and plasma (National Institute for Materials Science, NIMS) processes.
  - Technology transfer to USTO.
- Quantitative data collection for installation of PV and $HT_cSC$ systems, the following objectives have been selected:
  - PV system installation at Saida site.
  - Data collection for DC power transmission trough desert environment.
- Education and training on Energy problems and sustainable development, the following objectives have been selected:
  - Installation of WebEl system at USTO and Saida universities.
  - Development of PV materials devices and system.
  - PV application such as desalination, green innovation in desert.
  - Personal movement between Algeria and Japan.

### 5.2. Sahara Solar Breeder components

The most important objectives of SSB's energy policy and its portfolio include five basic strategies that are:

- Basic, applied, practical research and development, in Japan, North Africa, the Middle East, Africa, and other regions of the world.
- Industrial production of silicon from sand.
- Industrial production of cells, modules, panels, and other PV devices, building, operating, networking and monitoring Very Large Scale Photovoltaic Power Stations (VLS-PVPS).
- Environment monitoring and gradual implementation of SSB.

One of the strengths of PV is to be found in its decentralised applications. This is particularly true for supplying isolated consumers in areas of low population density, where the demand consists essentially in satisfying basic energy requirements. Other notable characteristics of PV are:

- Modular design enabling it to be extended according to need.
- The possibility of developing small businesses in areas of low economic development.
- Protection of the environment.
- Limited capital assets, capable of being used flexibly and in a decentralised way, and of being moved about over longer periods of time.

The developing strategy, by the SSB project, has been elaborated to promote the dissemination of renewable energies on sites where they are profitable compared to classical energies and to guide scientific research efforts in order to allow generalisation of renewable energy via mass production. The aims to be achieved consist of the contribution to a conservative policy for hydrocarbons both by increasing the renewable energy share within the international energy balance and by improving the living conditions of isolated communities. The first operation of installation of PV plant in Saida town, considered to be the gate of the Algerian Sahara, would allow on one hand the electricity supply and on the other hand to collect information about:

- Equipment behaviour in Saharan environment.
- Matching the systems with the electricity supply.
- Maintenance of organisation and management.
- Technical-economic system optimisation.

SSB will then ensure an energy/climate security with global justice and development of civilisation for whole world, a clever global development strategy for solving the energy and climate problems with existing solar grade Silicon production from Sahara

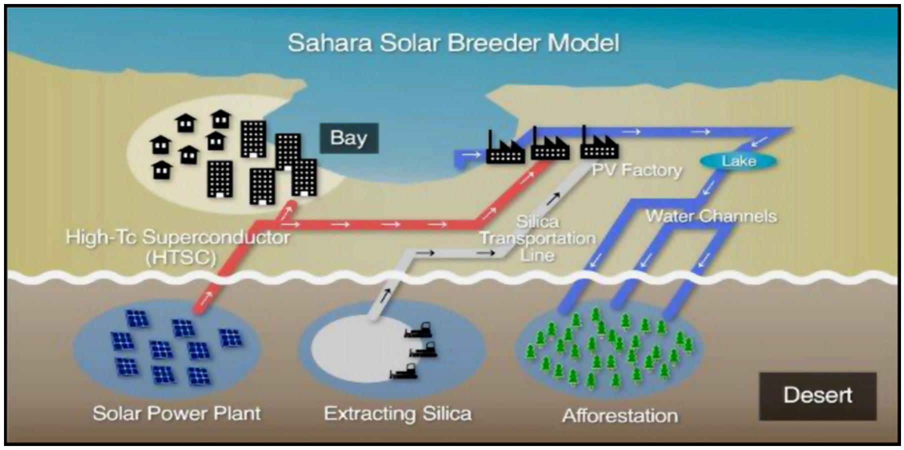


**Fig. 9.** SSB model, key to a sustainable civilization.

**Table 5**
Roadmap of SSB road and global energy superhighway.

| Year 2009 | 2010 | 2020 | 2030 | 2040–2050 |
|---|---|---|---|---|
| Planning | Master plan<br>First | Second | Third | Global energy highway<br>Final |
| SSB construction | First term<br>2 → 16 MW PV station<br>Si and cell factory<br>$HT_cSC$ transmission line test station | Second term32 → 512 MW | Third term1 GW → 16 GWExtension of SSB to continents | Fourth term<br>32 → 512 GW<br>Extension of SSB to the world |
| Management and finance | International cooperation<br>Sahara clean energy consortium | | Continental clean energy consortium | Global clean energy consortium |

sand technology for a world in a sustainable way. Sahara has a plenty of silica as primary material for silicon and of sun shine as solar energy source. Table 4 summarises solar cell materials and power generation capability (evaluated from material needs, efficiency, and natural resources). Moreover, SSB is an integrated community, socio-economic, industrial, agricultural, environmental, and science and technology development solution. In particular, through desalination and adequate irrigation technologies, it will help mainstream marginal desert water resources and lands back into national, regional and international development processes as shown in Fig. 9 [14]. Scenarios help us understand the limitations of our 'mental maps' of the world – to think the unthinkable, anticipate the unknowable and utilise both to make better strategic decisions.

### 5.3. *High critical temperature superconducting cables for DC electric transmission from SSB PV power plant*

The demand for power keeps growing at a scale and speed never imagined in the past since the need for more and more electricity is exacerbated. Moreover, demanding economic objectives as well as obligations to reduce greenhouse gases made a strong push for renewable energy sources (RES) with power generation becoming increasingly distributed and a growing number of generation facilities located far away from load centers. This situation has stimulated research on DC electric power transmission systems that are able to transport large amounts of electrical power, in contrast with the more common alternating current systems. For long-distance distribution, DC power systems present lower capital costs and suffer lower electrical losses.

In order to speed up the electric superhighway, the generated electricity from SSB, made up of a network of VLS-PVPS in Sahara desert, will have to be transferred to the North Africa, then Europe, Africa, and ultimately the rest of the world, via $HT_cSC$ that can provide, in compact dimension, firm capacity for base load, intermediate and peaking power, effectively complementing conventional electricity sources. Because $HT_cSC$ are compact and can transmit a large amount of electric power (up to 10 times as much power as conventional electric power transmission cable), it can utilise more effectively congested underground space where a lot

**Table 6**
Evolution of PV solar cell production.

| Starting date 2012 | 2014 | 2012 + n | 2030 | 2044 |
|---|---|---|---|---|
| 2 MW PV power station made from Si (20 tonnes) | +1 = total 2 → 4 MW | Total = $2^{n/2}$ → 64 MW | → 1 GW | → > 100 GW |
| Si plant (10 tonnes/year) | +1 | $+2^{n/2} - 1$ | | |
| p-Si cell Plant | +1 | $+2^{n/2} - 1$ | | |

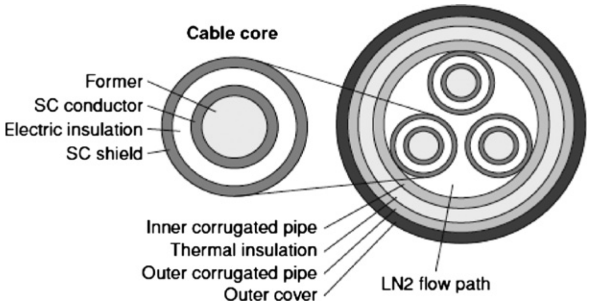


**Fig. 10.** Structure of $HT_cSC$ cable.

of piping and other units already exist. They are poised to help to reduce grid congestion as well as installation and operating costs. In addition, $HT_cSC$, using an $N_2$ cooling system (Fig. 10) [15], are characterized by the following advantages:

- Compactness and high transmission capacity.
- Low transmission loss and environmental friendliness.
- No leakage of electro-magnetic field to the outside of the cable.
- Low impedance.
- Effectuate transportation of solar-generated power from the Sahara.

## 6. SSB roadmap

The objectives established for the SSB project are focused on raising PV production every 10 years for a global superhighway purpose. Crucial objectives are targeted at substantially increasing and enhancing PV production from an initial value of 2 MW to breed into 100 GW in 30 years. Tentative specification and roadmap of SSB plan are outlined in Table 5. The electrical power will be obtained from Si based solar PV power plants. By assuming 2 years energy payback time, solar cell production can be doubled every two years to increase 2 MW PV to 100 GW in 30 years as depicted in Table 6.

## 7. Conclusion

Clean and secure energy is the key to a sustainable civilization, key to human security, key to a reliable energy supply, key to climate stability and bio-diversity, key for global and intergenerational justice and a key to more civilization and wealth. SSB ensures energy/climate security with global justice and development of civilisation for whole world. It has a clever global development strategy for solving the energy and climate problems with existing solar grade Silicon production from Sahara sand technology for a world in a sustainable way. The SSB project serves as the initiative for the super Apollo project [14] to provide the paradigm shift in global energy system.

## References


[1] Koinuma H, Kanazawa I, Karaki H, Kitazawa K.SCJ proposal @G8+5 academies' meeting. 2009.
[2] Fanchi JR. Energy: technology and directions for the future. London: Elsevier Academic Press; 2004.
[3] International Energy Agency report, website: http://www.iea.org.
[4] International Energy Agency report 2009.
[5] Boudghene Stambouli A, Traversa E. Solid oxide fuel cells (SOFCs): a review of an environmentally clean and efficient source of energy. Renew Sustain Energy Rev 2002;6(October (5)):433–55.
[6] Ezzeldin H. Global energy challenges and sustainable energy. In: Shell overview International conference on sustainable energy, technologies, materials and environmental issues. 2007.
[7] United Nations, World population prospect, the 1998 revision and estimates by the population reference Bureau.
[8] Wuppertal Institute for Climate. Environment and energy and the CREAD report. In: Algeria – a future supplier of electricity from renewable energies for Europe? Algeria's perspective and current European approaches. Wuppertal Institute for Climate; 2010.
[9] Renewable Energies Development Centre, website: http://www.cder.dz.
[10] Pietruszko SM. Photovoltaics in the world. Opto-Electronics Review 2004;12(1):7–12.
[11] Boudghene Stambouli A. Survey report on "Renewable Energy Manufacturing Facilities in Algeria" United Nations. Index 2007;3:382958.
[12] Kurokawa K, Keiichi K, Masakazu I, Peter Van Der V, David F, editors. Energy from the desert- III: IEA-PVPS task-8 report. UK: James & James Ltd.; 2009.
[13] Koinuma H, Kurokawa K, Kitazawa K, Fujioka H, Sumiya M, Furuya Y et al. Oxide initiative to make the dream of 'Sahara Solar Breeder Plan' come true. 17th international workshop on oxide electronics, WOE-17 Abst. 100530. Awajishima, Japan. 2010.
[14] Sahara Solar Breeder Foundation, website: http://www.ssb-foundation.com.
[15] Masuda T, Yumura H, Watanabe M, Takigawa H, Ashibe Y, Suzawa C, et al. High-temperature superconducting cable technology and development trends. SEI Tech Rev 2005 [No. 59].